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# PRODUCTION CONTROL BY "STEPPED" PROGRESS CHARTS.

*Paper presented to the Institution, Edinburgh, Glasgow, Yorkshire, Leicester, and London Sections by IR. Ernst Hijmans (Bureau d'Ingenieurs Conseil en Rationalisation).*

## The Scope and Aims of Production Control.

THE field of production control depends on the type of industry. In "flow" production, manufacturing processes are continuous and production control is reduced to measuring and balancing the "flow" speed through these processes. In "batch" production of standardised goods, there is the additional problem of frequent stopping and restarting processes. As manufacturing becomes rapid (as in woodworking) the cost factor of "process-change" looms larger and becomes a menace. Where product is designed to the demand of customers, production control is further complicated by the part that design absorbs from the total delivery time available. The present paper deals mainly with this last case, where the entire "bag of tricks" of graphic progress charting finds application. General machine building is a classic example of such a case, but its problems reappear in many other branches of industry.

The world is not yet the exclusive domain of "standardised robots." Factories where production is still the material expression of invention and artistic intuition, continue to supply a fertile growth of new apparatus, new shapes and designs in glass and woven fabrics which give colour to human life. One task of production control is to make modern manufacturing technique accessible to such factories by reducing and facilating process-change for their varied production.

To achieve this we have to: (*a*) Avoid unnecessary process-change; (*b*) reduce the cost of unavoidable process-change by choosing adaptable tools and by producing parts in the most economic sequence; (*c*) avoid unnecessary haste in details of manufacturing.

Point *a* includes the whole of *standardisation* for supplies, materials and the use of common parts. Point *b* explains why the modern

development of machine tools and their equipment is not entirely in the direction of continuous production. The range of the turret lathe, for example, has come down to very small lots, and production control can often provide a sequence of pieces to be made for which the main tool set-up can be maintained. Between one " batch " and the next, the resetting of one or two stops will then be sufficient. In the same way, progress charting in coloured weaving will permit to dye yarns in small quantities, but in such sequence of colours that dyestuffs will be completely used.

The scope of this paper does not permit to enlarge on the very interesting subject of process adaptability, but it is one of the factors that make production control a " money making " function.

Point *c*—the avoidance of unnecessary haste—is not in contradiction with the fact that short delivery time is as important for competition as low price. In a composed product—a machine, for example—there will always be a few parts (the cast-iron frame, etc.), that determine delivery by the addition of successive manufacturing days. Once this addition is reduced to its minimum, it is bad policy blindly to mark all pieces belonging to the customers order in question, as " urgent " and thus have some of these parts occupy men and machines which should be used for other work first.

Production control means : "*The right time for everything, and everything done at the right time.*" The right interpretation of this slogan can have a beneficial influence on *stocks* and on the amount of " work in hand." The importance of reducing these, from the point of view of investment and risk, is well known. On the other hand an increase of the average manufacturing duration is—in itself—an impediment to good production control and a sort of vicious circle tends to develop.

The larger the volume of work in the shop, the greater the number of items production control has to keep an eye on, and the more frequent the disturbance which always follows, when for one reason or the other certain parts are artificially " chased " through manufacture.

Production control should aim at maximum production, through increasing the speed of circulation, but keep the " flow " as thin as possible.

## Basic Forms of Progress Charting.

To place the elements of manufacture in terms of time is most easily accomplished by the use of graphs. Only on a chart the relative position of a great many elements can be perceived simultaneously, as is necessary for production control.

The types of chart most used are those which were developed in first instance by Gantt during his work with Taylor. From left to right there is a calendar scale. Under this there are

horizontal lines, each of which is allotted to one element of the production to be planned. If the chart is on paper (as in Fig. 1) the fact that work is going to be done on an element during a definite period, can be pictured by a coloured line under the dates concerned, at the heighth reserved for the element in question. If a board is used this line is replaced by a strip of coloured paper in a horizontal slot.

The type of "elements" controlled in terms of date determine the type of progress chart of which the main are:

(*a*) *Order-breakdown* in sub-assemblies and parts. (Fig. 1). (*b*) *Load-breakdown* where horizontal lines are allotted to load on shops, departments, or machines.

*Order-breakdown.*—As orders for composite product are received, it is necessary to divide the total delivery time and to assign one part to final assembly, another to the successive operations on sub-assemblies and important parts, and a first period to designing and working out of manufacturing data.

Fig. 1 gives an example of such order-breakdown for a series of centrifugal pumps. A number of horizontal lines has been reserved for each of the main components and a vertical column for each week. Load capacity required is expressed by coloured lines in the weeks, each line representing a definite load per week in one of the sorts of work that are enumerated under the diagram. An order-breakdown is always made backwards, starting from delivery and placing each load element in the latest week in which it must be available. The origin of the data for such breakdown will be discussed later.

*Load-breakdown* is the result of superposition of the different order-loads per shop section. A coloured strip of paper is made corresponding to each coloured line in Fig. 1 and is then inserted into a board. From left to right the board has a calendar-tape on which a date-line is moved forward. The slots in the board are in groups, the number of slots in each group corresponding to the total weekly load-capacity of each section of the shop (lathe, drilling department, etc.).

The main object of such order-breakdown and load-breakdown is to foresee as far ahead as possible any temporary overload that would result from delivery promises. In case that part of a new order-breakdown cannot be fitted in to the load-breakdown, there will be time to make the necessary adjustment, either by changing order-breakdowns or by reinforcing production departments. Even if these two means would not solve the problem, a compromise with the customer as to delivery will be obtained with less damage, if it is prepared beforehand, instead of resulting from back-schedule, appearing at delivery time.

The main features of graphic production control being thus defined, we will now examine more closely their main features and some of the typical difficulties of operation.

## The Load Board in Foundry Production.

In the foundry which delivers a non-composite product, order-breakdown can be rudimentary and production control will centre around the load board. As orders come in, moulding time and the moulding machine or group are determined and a coloured strip of paper is made out, the length of which is proportional to the duration of work. This strip is then placed in the board with the right hand end under the date on which the last piece must be delivered to the cleaning room. As the daily records on castings produced come in, the corresponding part of each strip is marked off in blue pencil. In this way any length of strip, not marked off to the left of the date-line, is back-schedule. When the last piece on a strip is finished, the strip is taken out of the board.

The board thus gives at the first glance a permanent view on the load situation, manifesting any back-schedule on the left of the date-line and vividly calling attention to such lines of production for which the sales department should make an effort to find occupation. In Figs. 2 and 3 the actual operation of the board is explained.

While the foundry load board is in itself a moulding program, it can be used at the same time to call for such preparatory work as making ready patterns, flasks, armatures, and cores.

Each strip has, at the left hand corner, a case which receives the signs, given in Fig. 4, so that at any moment the situation of these preparatory operations can be seen. They are sometimes controlled by a multiple date line as in Fig. 5. Between these lines there is a fixed period and all strips touched by the first line should have patterns, those touched by the second line should have armatures and flasks, and those touched by the third line should have started moulding.

A board of this type should express the "exception rule." When looking at it, attention should be drawn only to those things that call for action, everything running normal being less in focus. This is accomplished by the use of standardised, vividly coloured signs for each of the main causes of delay (pattern not ready, flask not ready, workman absent, etc.). Fig. 6 gives a close-up view on part of the board of Fig. 2 with these signs. Foundry boards of this type are in successful operation in many factories.

## Change of Program in Composite Product.

Production control has to contend with changes of delivery dates, fluctuations in factory capacity, introduction of new processes, and many other influences which demand revision of schedules and breakdowns.

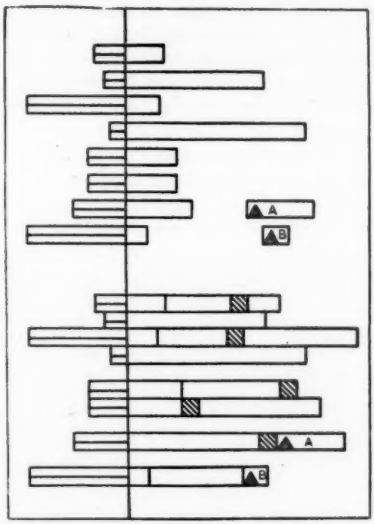



**Fig. 2.—Starting position for foundry load board. Inventory is taken of jobs in hand in the foundry and paper strips are aligned on date-line, so that date is shown, on which new work must be available. Jobs A and B are held by preparation difficulties. One or two next jobs are then assigned to each horizontal slot. Cross section strip is margin for unforeseen delay. Board is gradually completed in this way.**

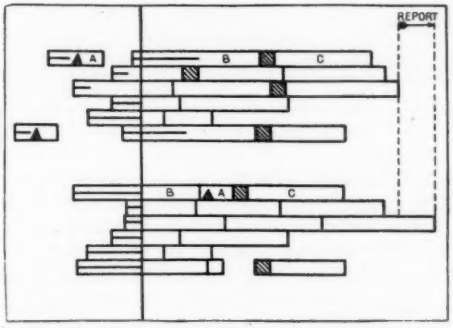



**Fig. 3.—Periodical readjustment of board. After some time blue-pencil-lines are ahead or behind date-line, showing work in advance and back schedule. Lower figure shows board after readjustment. In general delivery-dates can be kept by using reserved time-margin. On third line delivery will have to be postponed.**

Difficulties of this nature should be accepted as inevitable, as the whole function of production control shrinks to something secondary as soon as manufacturing can be conducted on lines that are " hard and fast " for a long period. The main difficulty of incorporating changes of this kind into progress charting lies in the necessity for multiple cross reference.

Repair of a heavy machine tool will displace by a week some important operation on a machine frame. This leads to regroupment of drilling and assembly operations which might touch a number of items belonging not only to the order concerned but also to several

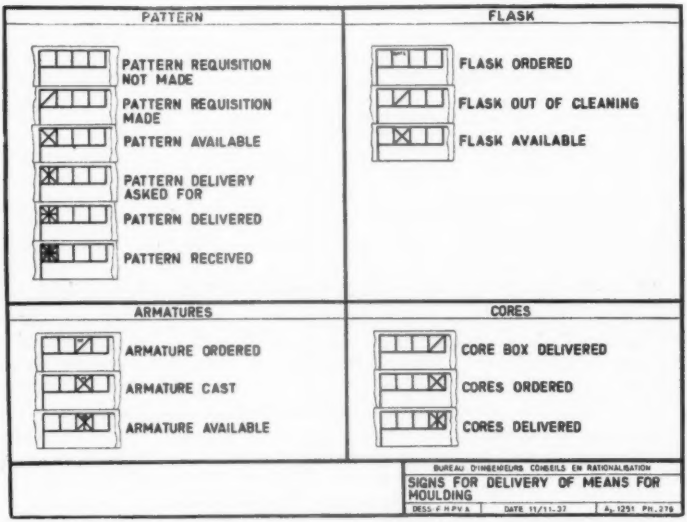



**Fig. 4.—Signs for preparatory work.**

other order-breakdowns. The one change may thus necessitate a nearly total revision of the progress charts. This revision is laborious and often has to be done in a hurry. Many graphic production schemes have not survived this stumbling block.

Besides shop incidents, such changes of program may originate from the fact that order-breakdown, if it is to be of any real use, has to be early, so that design and process planning are only approximately known.

As the definite drawings and part lists come into the shops, breakdowns will have to be revised and here again there is danger

that process charting becomes more costly in being revised than useful in commanding the shop situation.

Practice has thus evolved the following fundamental rule: *The precision of detail in progress charting should be in inverse ratio to the length of period covered.*

This law will be best understood by showing its application in a machine shop. Customers orders are sub-divided according to a standardised scheme of *manufacturing units*. A manufacturing unit will consist of one or a few important parts (like machine frames),

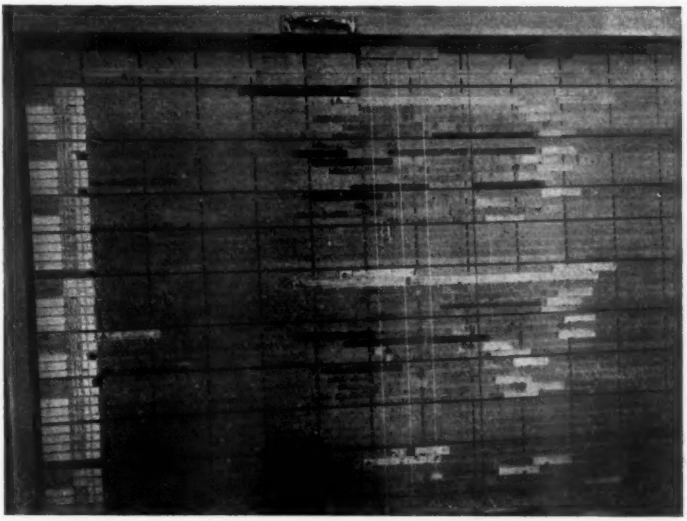


Fig. 5.—Board with three date-lines.

or in a sub-assembly, containing a larger number of small parts, having to go through similar manufacturing operations. The manufacturing units are at the same time the units of price-estimating and order-breakdown. Once these units thoroughly introduced, any customer's order can be estimated by comparison with earlier orders and an order breakdown can be made, even while detailed drawings are not yet available.

Progress charting is thus done in first instance in terms of large manufacturing units and gross estimated wage load per factory section, distributed over weeks, according to experience on previous similar units.

It is clear that changes in order-breakdown and load-breakdown on this basis will only have to be made if they displace considerable volume of work. The general progress charting thus obtained gives a stable and simple outline which can cover a period of six to twelve months and be a valuable guide to the general management.

One of the advantages of progress charting, done at this moment and in this way, is that the function of design, buying and tool layout can be included in progress control and that valuable time can be gained on these functions for the most difficult manufacturing units.

As drawings come to the shop, a second phase of production control sets in, that only covers a few months, but goes into greater precision. On each drawing received, manufacturing layout is made up and all material issue and time tickets are written. The order-breakdown for manufacturing units permits to assign to each work-ticket the week in which it should be given out and this week is marked on the ticket. In this stage the tickets carry no machine number or name of workman, only the group number of the machines being mentioned. By filing these work tickets per week and per machine group, an adding machine will give for each week the total exact load for which time tickets have been written out.

The time ticket file thus forms a redefined load schedule, covering about the two nearest months of the long time schedule, obtained from estimated order-breakdown. It will be possible in many cases to provide adjustment of overload, shown by this ticket file, while maintaining the general order schedule.

The last stage of progress control is at a still shorter period, usually about a week. It consists in giving out to the foreman of each shop the time tickets of all work he will have to do within the next week. These tickets are found together in the load-file mentioned above.

Each ticket carries (see Fig. 7) at the top a load division on which a blue-pencil-line gives the duration of the work.

The foreman has a board similar to that described for the foundry but with a large time-scale and a slot assigned to each of his workmen. He can place the time-tickets in these slots in such a way that the alignment of all tickets, placed with their blue-pencil-line in contact, will indicate the total load for each man. In placing these tickets, the foreman is responsible to choose the best workman for each operation and if he cannot place within the week the tickets given to him, this means that eventual backschedule can be obviated a week beforehand. It is by this " stepped " production control that long-term progressing can be applied, while keeping freedom of movement for all details that can only be progressively developed.

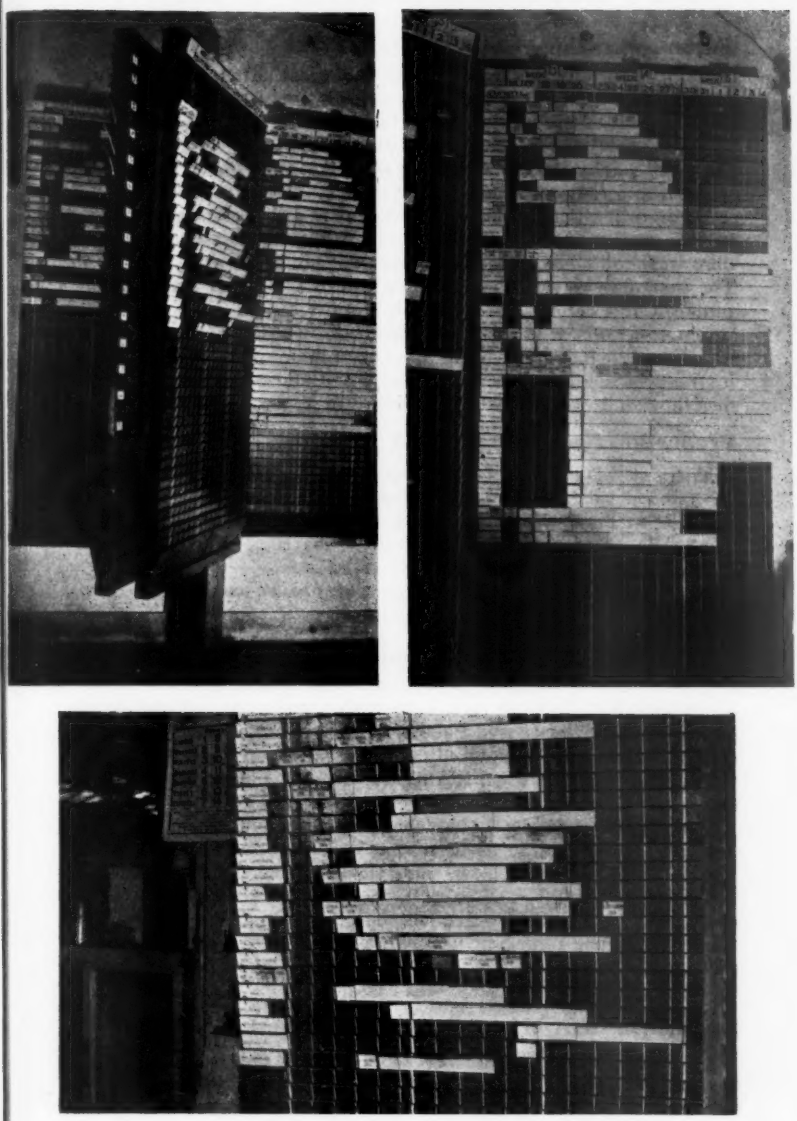


Fig. 7.—Progress-board in foreman's cabin, showing worktickets lined up in slots.

## Foremen's Responsibility.

Stepped production control has the great advantage of giving back to the foreman a part of responsibility which the older and over centralised production control had taken from him. It is neither efficient, nor just, to load on to the foreman the responsibility of customer's delivery-dates which are influenced by many factors over which the foreman has no control.

On the other hand, successful operation of a shop demands that the man in charge should know in detail the personal abilities of each man and should have freedom to use these abilities to best advantage. The assigning of jobs to individual workmen is really a foreman's function and cannot be done well from a central office. Stepped production control is the conscious reconstruction of the foreman's kingdom, but instead of being a vague domain of the rule of thumb, its freedom is enclosed within a period of about one week and within distribution of work over a definite group of machines.

## Production Control and "Red Tape."

There still is a good deal of prejudice as to the considerable cost for extra clerical labour that production control would demand. In practice we have always found a saving of clerical labour when introducing a good scheme of progress charting. This is possible, if another fundamental rule is observed—

*Progress control should only use data which would be necessary anyhow. No information, special to production control, should be necessary.*

It should be realised that progress charting is nothing but the writing in advance of indications of all sorts for action. Material cannot be given out without an issue ticket, material control should consist in filing these issue tickets, written in advance. The posting of this file is done automatically by the issuing.

We have seen that wage tickets are used in a similar way. Besides economy, the great advantage of interweaving production control with the daily routine is that those in command of action notice and correct eventual mistakes and have a motoric influence against any data lagging behind. If time tickets serve to post a progress board before going to the payroll, the board will always be posted, as payroll work cannot wait! On the other hand, if a foreman has to sign the time ticket as finished, his technical eye will discern anything abnormal in the piece rate or numbers that would not be noticed as easily by the clerical staff.

## Production Control and General Organisation.

It is not possible within the scope of this paper to enumerate the many reasons for which production control should not be treated as a problem by itself. Besides the arguments already

given, we would simply point out that progress charting is nothing else than a time budget and that there is no better base for financial and technical budgetary control. If a foreman has given to John or Peter a time ticket which should be finished by three o'clock in the afternoon and has planned the next job to follow, the fact that John is not ready at 3-30 will be brought home to him by a look at his progress-board and lead him to action about the loss in efficiency which is thus signalled. On the other hand the subdivision of orders into manufacturing units and the separate scheduling of these units in terms of estimated money will lead to a running cost control on each of these units and even on each of the departmental cost items of these units.

By having a long term production control as described, firms with long running contracts (shipbuilding, machine-building, railway carriage-building) have a means of making a monthly balance sheet with a fairly accurate profit or loss on partly completed work.

## Discussion, London Section.

MR. N. BALIOL SCOTT : The lecture to which we have just listened is of great use to the Institution of Production Engineers. This is not the oldest of the engineering societies, but its rapid growth in the last few years has shown it to be of importance to industry. Mr. Hijmans early in his address divided the manufacturing span in two, allocating the first three months to design and construction and the second three months to production. Some of the older engineering societies place all the emphasis in the first three months on what you are going to make. The production engineer transfers the emphasis from the office to the factory, from the drawing of the blue-prints to the processing of the product itself. It is just this aspect that Mr. Hijmans has been discussing to-night which particularly distinguishes the work of this Institution from those others.

To me the most important aspect of Mr. Hijmans' address was the emphasis he laid on the time factor. I was speaking on one occasion about the conception of management-mindedness, and in trying to analyse this I found that it comes down to : First discovering what the facts of the situation are and facing up to them ; the next element to be considered is time ; and I think the third one is simplicity. If you can once really ascertain the facts, view the problem in terms of " time " and then get down to the simplest way of doing the job, I think that the fourth element, the element of cost, is practically taken care of. Now I noticed specially in Mr. Hijmans' address that everything he said emphasised the time element. For every single job, whether it was to be done at one machine or by one man, in one hour or in one day, or whether he was referring to the whole factory load months ahead, he described the method of controlling the time factor.

Further, he emphasised towards the end of his address the factoral aspect " who " had to do " what,"—I think possibly the only question on which we can have any doubt is that of simplicity. Is this really the simplest way of achieving the objectives he set out to tell us about ? Now *I* personally know of no other simpler way than this general method of getting a chart and controlling graphically each step in production.

Mr. Hijmans at the beginning brought up the question of " chasers," and the difference between the old fashioned chaser method in a factory and this method of planning each individual job ; incidentally I was amused at seeing recently an advertisement

reading " Chaser required for Scientific Factory Organisation " : I think there is a little training of the management to be done there !

I would like to refer to one of Mr. Hijmans' early charts, where as far as I could see he doubled up his bars and reproduced them underneath on the inverted battleship. I could not see the object of that. It seems to me he is adding together times in different operations or even in different sections of the factory, and the value he gets out of that " inverted battleship " chart I could not see.

There is one point of technique in which I differ from him somewhat and that is that I see he adopts entirely the method of the planning board. I have always myself used the Gantt chart in its original form as a piece of paper, ruled out like he has his board, on the desk. I would like to know in what way he considers the board an improvement on the ordinary sheet of paper. To my mind the sheet of paper is more flexible. You have it actually on the table where the man is giving out his production cards. There is no need to get up and walk to a board and take something out, and if you have to carry it about from one office to another it is in a very simple form to carry, whereas I can see he would have to have a small staff for the movement of some of his boards.

Another thing I did not quite follow—it has always seemed to me one must keep two quite different conceptions in mind on this planning. One is the load building, that is, definitely building up the load ahead on a certain group of machines or a workroom or factory, and the other is the daily planning. I did not see the allocation each day to each particular man or to each particular machine of the work to be done on that day, though I think at the end he was bringing out that difference. He showed how the load building was done on charts, but if I understood him aright his allocation of work day by day was actually done by means of the material dockets or the production cards. But I understand that in his early explanations he combined together on one board the allocation of work, and the load building and I would like a further explanation of how he combined that into one, because the problems of load building seemed to be quite different from what he has to do for his daily allocation of work.

Just one other point—Mr. Hijmans started off at the beginning saying that he was going to describe to us one particular form of this method of step planning. Now as we saw some of these later photographs they seemed to jump about from one industry to another. To what extent does he have to vary and adapt this general type of step planning to the different types of factory work ?

MR. HIJMANS : The question of simplicity is one that always stands in the foreground, but it gives me the opportunity of warning

against a mixture of two aspects which I always had to encounter in my twenty years' experience. Even after having had to explain this type of board regularly, I have not yet succeeded in convincing a manufacturer by description only. I hope I have had a little more success with you because most of you are already conversant with the problem. But if you tell people about a general load board, an order-breakdown, they get an idea that it is extremely complicated, and it is only by working it in that we have been able to overcome that feeling.

You can have several steps in such a planning scheme, and if you explain the scheme it is rather difficult to visualise how they work together ; but in practice responsibilities are sub-divided and coupled in such a way that each man who works on one of these boards sees that his responsibility is completely covered by the instrument we give him. This is where the question of movable graphs has not thoroughly been understood. We have means to see the general load of the factory. That is done in one spot only, in the central planning or production department, which is near to estimating and near to general management and serves general management only. Secondly we have the rate-fixing and load control point, where there is no board at all but just a file per section and per week of prewritten work tickets, and a list of loads which gives to central planning a check on the data. From the rate-fixing file to the foreman, who feels that he is an independent factor and who does not bother at all what they are doing at central office, somehow wonderfully a man comes with an envelope of future work tickets. " Here's your lot of work tickets for next week. Shall we place them together ? " and that foreman is entirely discharged of the responsibility why such a work ticket is placed in that particular week and not in the next. All he has to do is to allocate to his men the tasks that central planning has brought to him. So that the idea of " stepping " is coupled with the geographical distribution and the responsibility distribution, and distribution of the degree of accuracy. There are three entirely different instruments co-ordinated by the fundamental development of each order.

The man who estimates is already wont to have a certain time motion in accepting orders. Well, we give him a board in which he is not bothered with anything else, but just gross operation load in gross periods. He does not calculate in weeks but months, and he can accept such load in August and such other in July. That is the chart in the form of an inverted battleship summary graph on the breakdown. The battleship is the adding up of the different elements. This Gantt chart, which is the real paper Gantt chart, goes down to the second step, where it serves to allocate weeks to drawings and to allocate tickets to weeks. The whole higher

management problem is solved there and does not trouble the foreman. The foreman need not even know any client's name.

Now, as regards boards, in general we have no movable boards outside the last foreman's board, and that folds together and you can take it under your arm. Generally we take the view that if there is no need to move, the Gantt board has a great advantage over the Gantt charts, and has easy adjustment. As you sometimes have to shift loads the chart would be very troublesome.

But there are cases when you can write to clients, and where there is a constant re-adaptation of general planning. I will select just one example. It is well known that the General Post Office makes a yearly programme of its telephone installations. Now this has to be planned ahead, and as County Councils are getting difficult, or more urgent orders come along, you might have a building where such and such an installation should be finished in January, but there is an emergency case so that the client himself, which would thus be the G.P.O. would go to the chart and reorganise the general programme ; the interesting thing is that this can be done at the general management level only because the allocation has not yet been done and so is not disturbed. This is the main reason for " stepping." It is not very difficult to shove and remake loads and to remake Gantt charts for gross breakdown only. It is killing to have to remake allocation. Therefore, we use boards for general load. Generally the boards are not moved, and are used where we want to move strips in them, and these cases are very frequent.

Another great advantage of boards exists where we want a direct and automatic connection between the use of the documents which take the place of the strips, and the poasting of the board. We have a special form of board which enables us to use full-sized cards folded as strips. You take these documents out and in that way post your board. This cannot be done with charts. These are the two main reasons why in many cases we use boards.

We also use Gantt charts on paper, in cases where changes are rare and when the general breakdown will not often be changed for one order, and where we have to transmit orders in a fixed form to a decentralised service. Both forms of Gantt graph have their usefulness and should be applied either the one or the other as the case demands.

With regard to the question of variation of industries. I must mention that planning is not influenced by the type of industry in the sense of what they manufacture, but the type of enterprise and the influence it has to content with.

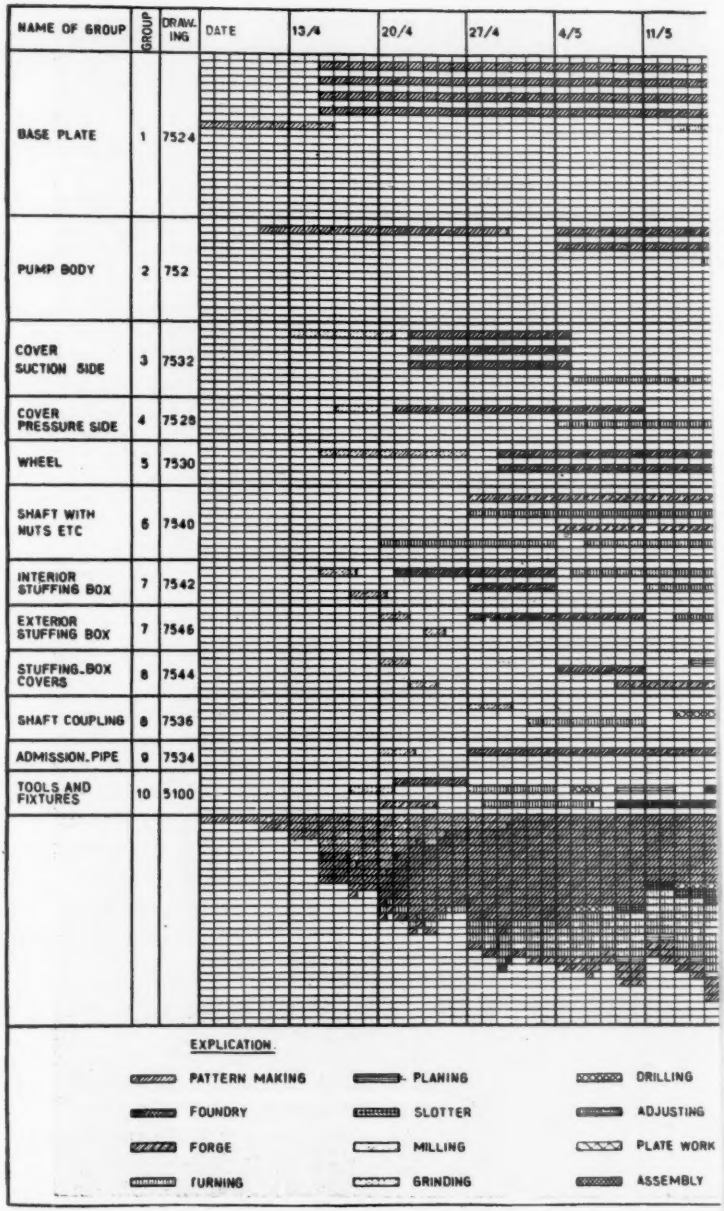
Mr. Gerrard Smith : I and my two assistants who are here to-night feel very gratified after hearing this lecture, because we have been going through exactly the same thing ourselves, and with one-tenth of the experience of Mr. Hijmans the similarity

between what he has explained and what we finally agreed on is really remarkable. We have not any long term views, so we are not worried with that difficult part of it. We receive a weekly order which has to be completed in roughly three weeks, and we have so many operations. I think we have about 1,500 different pieces to make per week in wood, with an average of six operations each. Now we have a planning board and the first thing we do is to make out a piece-work card on every operation, which is the original document on which we pay money. We allow $x$ minutes for both setting and running, and we mark on the top of each card, to a scale of half-an-inch to the hour, the time that the job is going to take, and we place all these in the rack, spread out the edge of one card against the mark on the top of the other, so that we can see the total time which is given, but before we have done that we have done the arranging of cards which Mr. Hijmans describes so as to get the minimum possible setting time. For instance, we do all our rectangular sequences first, then we have the grooving tool on each of the rectangular sequences, then the radius tool, and so forth. Not only that, but we place all our long pieces first in rotation so that any pieces with the same dimensions can be cut to the same section but shorter as we go down the scale.

We also use a card which stays in the board behind its piece-work card as long as the piece is not being operated upon. If it is being operated upon it is on the machine, so that as soon as this progress card comes to the board it is joined up with its piece-work card and brought down into a lower section of the rack, so that we can see along the top our total load going to every machine, our board being incidentally arranged by machine, and we can also see the amount of work ready to be worked at this very moment and in sequence By having a time scale on the bottom of the rack we can say that this job will go off at 11-30 and that at 12-30—some of the jobs actually take five minutes—and, in the same way as Mr. Hijmans, we can go and ask for the job at the time it should be finished.

We also had the difficulty Mr. Hijmans experienced of getting the foremen to operate this at the beginning. They did not want it. They hated it, and so we took it completely off their hands, and we worked it by clerks and forced the thing upon them ; but before many months were over they began to take interest and finally they wanted it back, because they saw that part—and a very important part—of their job had been taken away from them, and now I will say that the thing is working like clockwork.

But I would make one warning to anybody who is going to start afresh. What I thought when we first started was that if a railway could say where every one of its trains would be next Wednesday week at 12-35¼, we should be able to say the same about parts


NAME OF GROUP
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13/4
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BASE PLATE 1 7524
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COVER PRESSURE SIDE 4 7528
WHEEL 5 7530
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EXTERIOR STUFFING BOX 7 7546
STUFFING-BOX COVERS 8 7544
SHAFT COUPLING 8 7536
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EXPLICATION.
PATTERN MAKING
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Fig. 1. Ord

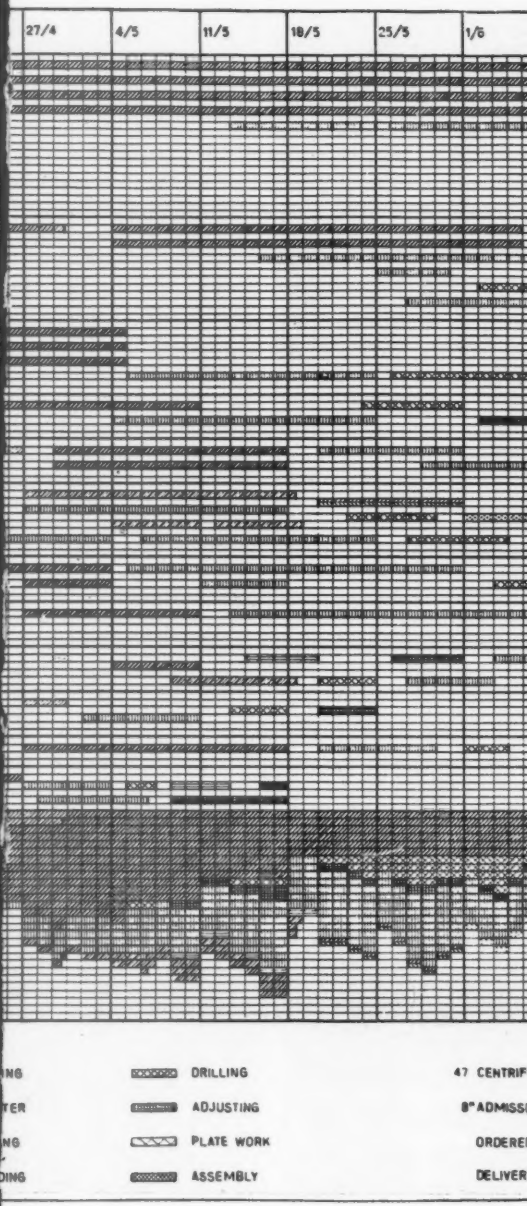
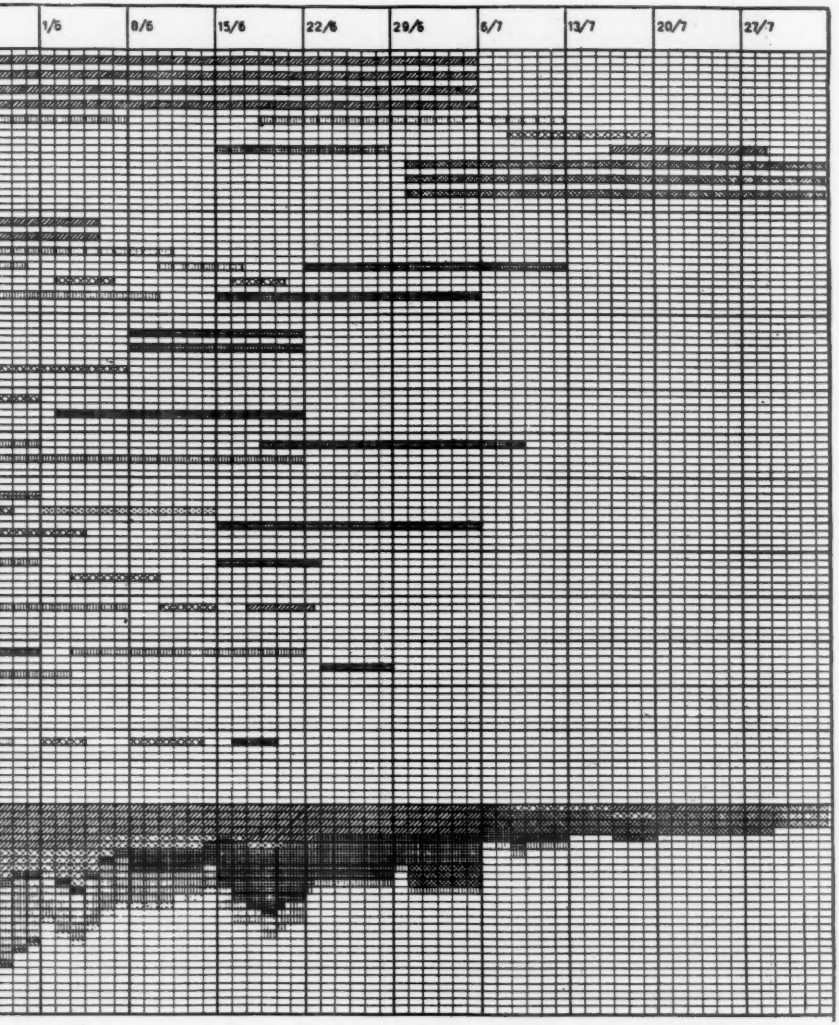



Fig. 1. Order-breakdown for a series of ce



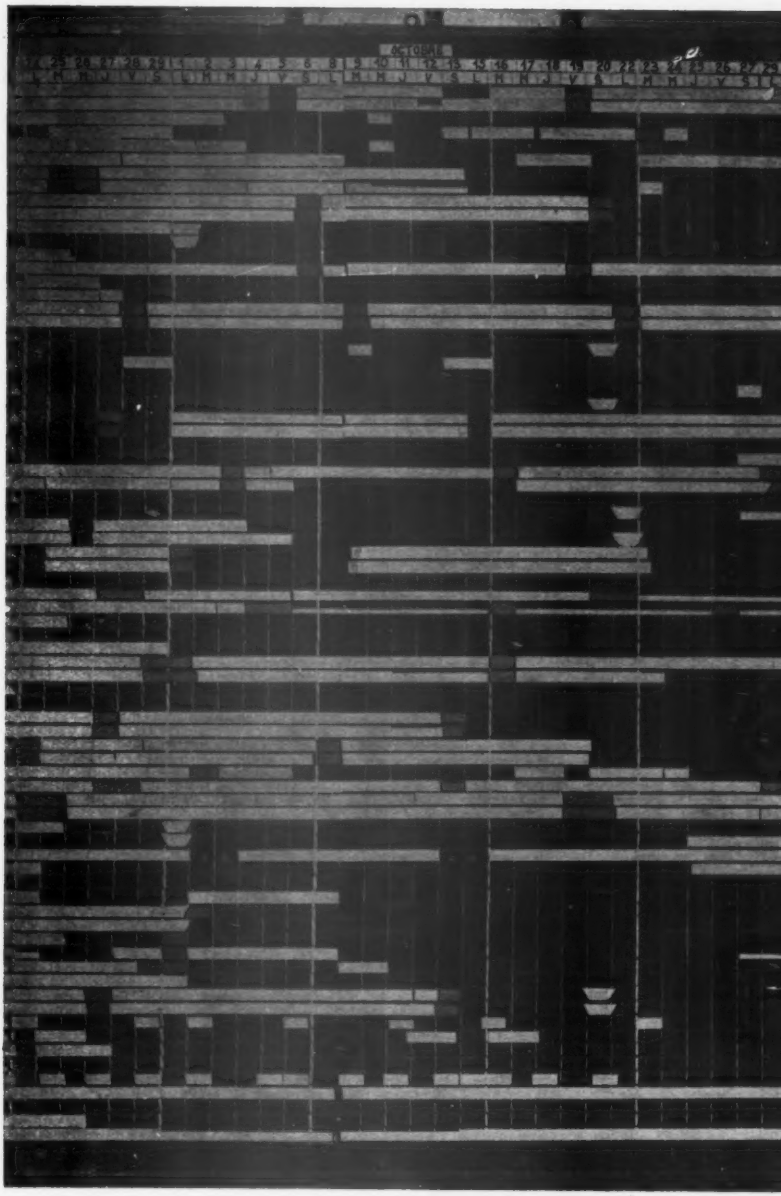

47 CENTRIFUGAL PUMPS

8" ADMISSION - PIPE

ORDERED: 8/2-32

DELIVERY 10/8-32

a series of centrifugal pumps.



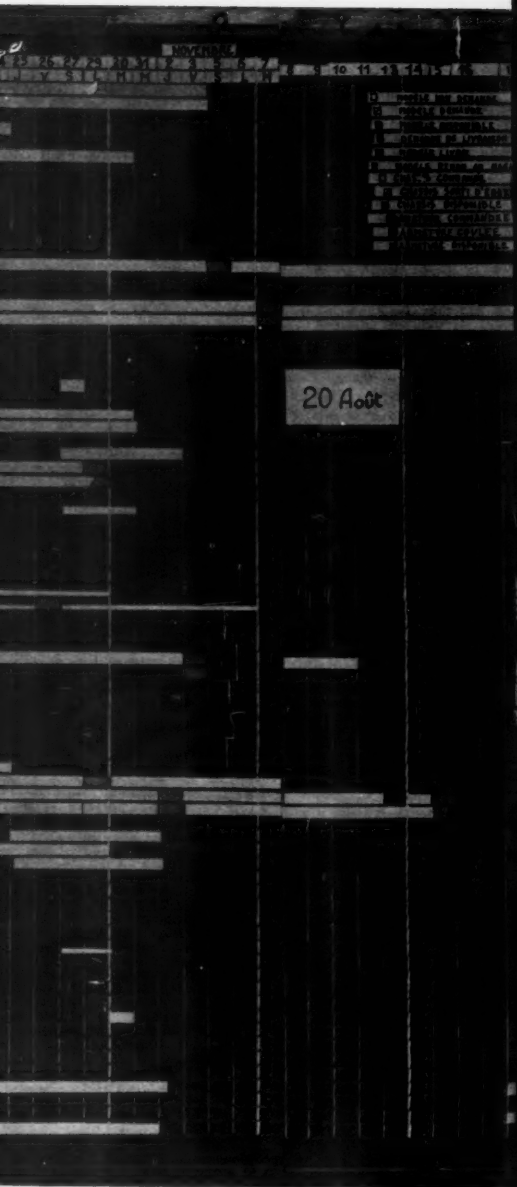
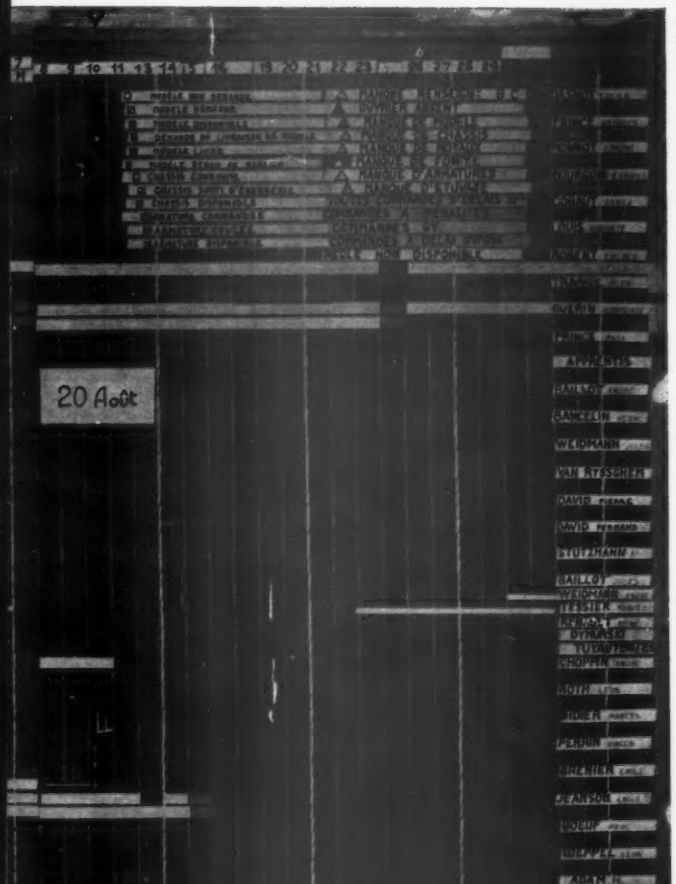



Fig. 6.


20 Août

in our shop. But we soon came to the conclusion that either running railways was child's play, or railway men were supermen.

MR. HIJMANS: I can only say that I almost completely agree, but I heard you mention wood and short time operation, and I would give the warning not to go too far. As I have already indicated, in machine shops there is somethimes a tendency to doing this and admitting small time tickets. Now we always do away with that. The small time ticket is not an advantage. If you give a man three minutes to do an operation in and you give a time ticket out, you are not sure whether he will clean his machine in this time ticket or in the next, and that might make 80% difference. So it is completely useless to give him a time ticket. And therefore our general rule is that we do not work with time tickets in metal work under a quarter of an hour, and not over three to four days. If we have a long job we divide it into batches so that the workman will feel what he has done.

Now in woodwork that depends—if it is furniture wood work which I suppose it is, there is detail, but there should be quite a lot of half continuous work. There is a type of industry which we call " intermittent-continuous." There should be adjustable coupling of machines and there is another thing, if you have subsequent operations in the wood-work, say long sawing, short sawing, cutting off, which can be subsequent operations, it is often an advantage to sacrifice a few minutes an hour to couple operations. These sawing operations will lose less by doing that than by working pieces and out of piles making a large number of time tickets. We have worked in furniture planning on these lines, and we have always kept rather to tools and combined the work as you see, and I would warn against wanting to plan too minutely. It is neither good from cost point of view nor from that of progress control.

MR. GERRARD SMITH: I must say this, if I may, that we do generally have operations where we can do that, but since we pay on a man's work ticket for every minute of value it occupies, we have to have it even though it is not essential for control. We pay the operator for the minutes produced on his work cards at a flat rate, so that if anything is omitted we should be in error.

MR. HIJMANS: When we have these small jobs we keep to piecework setting, but we have men specialised in small jobs. There might be two machines available, of which one may be a small job machine, and the man will know what he has done in the day and just put the tickets through, but we do not consider these tickets individually. We know the time spent on them covers a certain amount of work, and we have time clock giving overall time and the bunch of tickets.

But I would warn you against planning on too small a unit. You must not try to be more accurate than you really can be in a

given factory. There should be truth in the accuracy of administration of a factory, and as I have said, I have seen quite a number of failures by people who were trying to catch flies while elephants went by.

MR. B. H. DYSON : I consider our fluent lecturer has pointed out quite clearly, although I do not think it is always realised, that the fundamental of efficient production planning is, first to know your production commitments and your production capacity in terms of hours of work, under each machine tool and labour type classification. I have had the job of work, in two factories of the lot and batch type of production, of installing a method of controlling output with control boards, and after walking around the edge of the production control board for awhile, I found there were one or two definite points of procedure that one had to face up to. The first was to sell the method to be adopted to the foreman, charge hands, and setters, on the terms that would help them to realise the possibilities of its real assistance to them to further practical results, because no matter how well I did my planning, if they did not intend to work the plan, well, it just simply did not work.

I found that in order to achieve this I had to adopt a simpler method than that Mr. Hijmans has put before us, and although the basis of controlling was similar to his I started first with a " Work in Progress " control board and gradually worked back to Gantt chart pre-planning. I think it is essential to commence with one department or section at a time, and preferably with one working on initial operations, such as a Bakelite moulding, die-casting, or automatic section in which subsequent operations are not prevelant.

The type of control boards used were divided vertically into departments or sections to which they applied, and these divisions were divided horizontally into card pockets, a pocket representing each machine or bench available. Starting off with a " Work in Progress Board " in which were placed the operators' piecework cards for the job being worked on, so that I had a minute to minute visual record of the actual work in progress.

Now with this visual record of the actual production I was able to win the foreman over to the fact that he could see at a glance how many of his machines were actually producing, what they were producing, and if they were idle, by the use of appropriately labelled cards. It gave him the satisfaction of bringing to my notice the reason why, such as, " setting-up," " machine breakdown," etc. His delight, of course, was to be able to indicate " waiting for material," or " waiting for work." This was followed up by installing a " work allocated board " that was identical in layout, and placed in close proximity to the first board, and was the work-feeding board in which was placed the order and piecework cards, of the work loaded to each machine or bench, and in the sequence of priority. Only after the foreman has digested this portion of the procedure

and realised the practical aid of the control boards is it wise to proceed to machine and labour work loading and to carry forward with pre-planning by means of charts.

I have found it possible to achieve amazing results of increased production by the controlling methods but would emphasise the necessity of keeping the method adopted as simple as possible with no frills or elaborations and fully realising the fact that no system will achieve results simply because it is a system.

MR. HIJMANS : I quite agree, and we often begin by simply having a work in progress chart. The start should be only one job ahead. The data in the last foreman's chart I showed is exactly the same, but under the date line is work in progress, because we always have a duplicate ticket. I can also see the work in progress : the work in progress is simply the first card in the chart and the other cards are your dockets of the next board. With this data and with these dockets we also have a length scale, so that I can see if the next card represents half an hour or six hours, which is very important as it enables the foreman to look forward a little more and warn him beforehand about tools lacking and things to be done by him. But I find that this method of extending the chart by putting a scale on the pocket and making it a little longer really helps us and is not difficult to understand for a foreman.

MR. C. S. WATSON : Has the central control office any communication during the week with the allocation board or the shop foreman ? You say that the shop foreman received the set of tickets for a given amount of work. The foreman allocates the work to various machines for the period during the week. The foreman then finds that his allocation has reached over the load time, or under, as the case may be. Is it necessary for him to make personal communication with the central office, or have you got a daily runner between the central office and the foreman ? The speaker makes no reference to the shop chaser. Does he really think that the shop chaser is unnecessary ?

MR. HIJMANS : I will answer the last point in this way. The most destructive man in the shop is the chaser, because a chaser is a man who is kicking back five things to get forward one ; and the first thing we do by putting these allocation boards into the shops is to make chasers entirely unnecessary. There is one thing we do have, which has been worked for ten years in one particular shop, making a range of products from bottle washing machines to bottle and gas plants. Every morning and every afternoon the man of the allocation board gives out a *transport order* to the transport labourer. He is not a chaser, and he goes to lathe A and transports the work to milling machine B, etc., till the work is entirely finished the last " step", the allocation being so close to the shop, we have every detail in hand, so that there is no work for a chaser.

As to communication, it is like this, we determine the frequency of contact between the main planning and allocation by the relative importance of deviations that may occur. Usually we give out the work every three days. If we think that the average unforeseen case would be unimportant enough not to upset a week's progress we give a fortnight, but it is not a question of sending down a packet of cards, it is a question of the central planning man being seated with the foreman and putting in the cards with him, noting at that moment all back schedule. It is at that moment that the cards are shoved forward, and if there is any shoving forward like this it is the main planning man who knows back schedule ; and as you can only fill a week's space up with a week's work, and not with a week and a half, if there is any back schedule work to do, main planning will have to take back part of the dockets. The filling of the board replaces conferences that often are occasions for the bad boys in the shop to play because the foreman is away, the work on the board is quickly done and does not admit of much talk about the weather. They sit down and place out these cards together. The foreman will say, " My dear fellow, you will have to take that packet back. I cannot place it." There is no argument about it. The main planning man goes back and then sees the works manager. " Sir, I have a back schedule of half a week, and I have placed this and that order. What is there to do about it ? " If of course there is a machine breakdown the foreman has orders to notify, but only on a large machine or a special machine breakdown would work back into the next step, and these cases are extremely rare. But the main connection is the board. It avoids " passing the buck." It is a question of transmitting responsibility by working together. The foreman has a task which he has accepted to do for the next week. His responsibility is to do that task, because he has accepted freely to do it. If something goes astray and he wants that task altered he applies to have it altered and in this way he takes responsibility. In many cases he will find something to do about it. That will depend on his initiative. But the chaser, as I say, is against reason, and there should not be any work for a chaser in a good shop.

MR. STRATTON : Is it your opinion that a control should only control major parts and the remainder look after themselves ? You have heard Mr. Smith say that we produce 1,500 different parts in the course of a week. Do you think we should control the whole 1,500 or only the major parts and progress these ?

MR. HIJMANS : We have there the problem of interchangeability of production. If you are woodworking there are only certain special machines, but you will have a certain number of cut-offs and length saws. Well, there I suppose you have simply to add up the minutes and then distribute them in a general plan and then as you come down put them down into that week, and thus the orders would

be subdivided in volume of work to certain compartments of interchangeable work. And then, even in the main planning load, specially on that long term board, certain special machines which can only do one job are placed, and if you cannot do that particular job you cannot take any more work without increasing that capacity. In a machine shop you will have one or two boring mills. Often in a load board you will find one line giving one machine, because that one machine is a section by itself and it is not interchangeable. We take out some special machines and treat them individually while we treat the other machines per section.

MR. WHITE : I think we certainly must offer a very hearty vote of thanks to Mr. Hijmans for coming along here this evening. He has been very instructive, and I think after his explanations we can see further opportunities of applying Gantt charts and charts of a similar nature to our factories. I was certainly very interested to hear that he was able to apply the Gantt chart system in a factory which had been run by a foreman for a matter of twenty-five years and he was able to sell the idea to them apparently quite readily. I think it was very good selling, and I also think that he must have been able to impress them very much with the advantages of the scheme. I think it is a very good scheme that he makes the foreman very largely responsible by running the chart in his own department, the major chart being in the production office, because that does enable the foreman to feel that it is still his job to manage his shop or deparrment. I rather doubt in my mind the advisability of making up wages in the department, though apparently that was in part due to the necessity of using up the man's spare time, but I am rather of the opinion that wages should if possible be centralised. I should like to have seen the application of the charts to sub-assembly work and assembly work as well as just to machine sides of manufacturing, particularly on quick assembly work and quick sub-assembly work, as to chart that accurately would be I imagine somewhat difficult. There was one other point, and I am going to defend the chaser a bit. I expect some of you have got them. I still think, sir, that they are necessary evils. I think you have got to have them to a degree. We all have tool breakdowns in the best regulated factories, and believe me if we did not have chasers running round sometimes chasing up tools from the tool room and tool parts, well we would have a pretty difficult time. We do want chasers sometimes and there is a considerable amount of chasing to be done then. For instance at the inception of new models when we put through possible designs of small parts, they have probably got to go into five or six different attempts in the design department and then into the assembly room, and there must be chasers specially attending to that job, and I feel that they are necessary evils in many instances.

## Discussion, Yorkshire Section.

MR. A. SYKES: We have been particularly fortunate in having a lecturer to-night in a man of such international reputation as Mr. Hijmans. We very often listen to a lecturer and say to ourselves when he has finished "Well, what he has said would be all right applied to so and so's business, but it would not work in ours." I think we all feel to-night that he has said something which would fit to each of our individual businesses. I personally feel that there is a great deal which would be applied to our own business—that he has met the same kind of difficulties that we meet, and that he has really faced them.

Mr. Hijmans mentioned very short date deliveries. I think he referred to a cardboard box manufacturer receiving an order in the afternoon, to be delivered before noon the following day. Many of us are faced from time to time with orders of that kind. Some of them are so short that it seems almost useless to go to the trouble of writing out a lot of forms, because by the time the forms are made out the work is, or ought to be, finished. We also get breakdown jobs, when in spite of the promises we have made to others, someone comes along and impresses upon us that here is a breakdown job which should take precedence over everything else in the works. I would like to know how he deals with a situation like that.

There is also another type of customer—a very valued customer. You have given him a quotation and a promise of delivery, which you think is a faithful promise, and he says "You are not helping me, and I feel that you ought to give it to me in half the time," when you know you have already promised all your capacity to various other customers, but he thinks he is the most important of the lot and that you must put all your work on one side for him and upset all your planning. Then there is the question which most of us have been faced with during the past twelve months, when we have had orders coming in about twice as fast as they were going out. In a case like that, do you begin to plan your works for a year or eighteen months ahead, or do you leave it until the time is getting nearer? It seems to me that if you begin to plan it now you are going to want a planning staff twice as big as its normal size. In the meantime, perhaps, some new conditions have come along and that means your planning is entirely upset.

MR. HIJMANS: First of all, there is the question of small jobs. It is very important to know that one should not write job tickets under a certain size at all for progress or any other use. Many efforts of progress control have been wrecked by the fact that the same space

on the board was used to drill two holes of $\frac{1}{4}$ in. as to turn, say, a turbine shaft. We have a rule that no job ticket should be under half an hour (just to give an average time that would vary, according to the type of industry). If a driller makes two holes in a piece and gets five minutes for it, and then goes on to another job of five minutes, and so on, the object of the separate ticket would be to separate the cost price result or the piece-rate result of the first operation from that of the second. This object will not be attained, because the shifting of a small element of the operation from one ticket or the other will give 50% difference. This is a thing not sufficiently recognised.

In my young engineering days I was a second assistant superintendent in a shop building the marine steam engines of that day. On such a machine we would have a lot of small civers, stuffing boxes, and all sorts of things around the cylinder that were to be drilled and we had one job ticket for the loose parts of the cylinders. We had another ticket for drilling loose parts of valve gearing. Everything that was not worth while to give a ticket to we simply put on to one of these collective tickets, and we knew by experience what such and such a machine would average for total time for all these small parts.

There should be common sense and a sense of relative precision. We do not go and measure with a micrometer in the forge. I might point out that the whole business of progress control by steps gives an excellent opportunity of judging and combining each step and specially for preparing these combined tickets. Where we have to investigate a machine shop, the first thing is to look for small tickets, and if we find them they will not last long. It is astounding how people are not aware of the percentage of clerical work that will go into the small volume of time that these small jobs represent.

I would answer more directly the question of small orders. First of all, we have a special series of numbers for small orders under a certain size, and they are mostly shunted directly to the appropriate section. We reserve on the general load board a number of lines for these small hurried orders or for non-breakdown orders in proportion of their total average importance. In many plants this can be done and it is a simplification which is often neglected. We can, however, deal with these orders in detail on the second step. We have the tickets to write, anyhow, and there is no extra work for these orders because they will be filed into the week in which we must make them.

Regarding the question of breakdown orders and forced deliveries, as I would call them. You cannot have the toffee and eat it, so it is a question—if really there is somebody who has the right to force you—to choose on to whose corns you are going to walk, and I think it is a definite advantage to be able to choose, and that is

what progress planning can do for you. You have a permanent record of all you have promised and you can choose where you will break your word. It is possible to reserve manufacturing possibility for orders expected but not yet taken. You have estimated for those orders, so there is no objection to putting it in the general load chart in the form of paper strips of a special colour. The advantage of stepped progress planning is that you can plan very far ahead and very approximately. In the second step the estimate will be corrected with the drawings coming in.

As regards the question if you have new machinery and changes, I think it is a very great advantage when you are proposing to buy a new machine to know what you will be able to do with it next year, as you have load boards. I think the advantage of step planning and long term planning is of value in calculating the value of an investment, instead of basing yourself on the theory of what you might receive for it. Therefore as to the equipment side I think it is a definite advantage to be able to plan longer.

MR. H. C. NEWELL: Does Mr. Hijmans schedule on this step planning for jigs and fixtures and special machinery which are essential before actual production starts on any particular order?

MR. HIJMANS: That is certainly an interesting question. The practice is this. As we plan, the "board microbe" gets into the business and you see boards everywhere. The main schedule, or order-breakdown, calls for everything. The jigs and fixtures are noted by signs as far as they are known beforehand, and for the rest, as the drawings come down. We often can give an estimate of total hours on fixtures from preceding orders, and as the progress control accumulates data, we are able to say, "Such and such an order-breakdown will ask for so many fixture hours." The draughting room especially is an excellent thing to have planned. I insist on that, because it still seems to be considered a sort of offence to ask a draughtsman to estimate and note time on his work. I do not see why. Personally, when I have said that I thought I could develop that idea in three days, I am rather vexed to take four days, and the effectual production of a designing department goes up every time you put a progressing in without driving the draughtsmen. I am not for driving men, but I believe in rendering everybody conscious of his own degree of efficiency compared to what should be his own free acceptance of a standard, and that is how progressing for the drawing office should be seen.

MR. F. GROVER (*Section President, who presided*): May I just ask Mr. Hijmans whether he would say that the words "work analysis" were equivalent to "work breakdown," as he has expressed it? I think in many of his remarks I translated "work breakdown" as "work analysis," and I wondered whether that was causing any confusion.

MR. HIJMANS : Generally, " work analysis " is understood to mean studying movements of work. I think it is not as good for our purpose as " order-breakdown," because here we have the analysis of an object. One could say " order analysis " if you prefer.

MR. GIBBONS : Following Mr. Sykes' remarks regarding long planning, I appreciate Mr. Hijman's answers, but how would you budget for outstanding quotations, promises for which have been made, but orders not received ?

MR. HIJMANS : I am giving a technical answer for that. In the load board we have, as I said, colours giving the main type of orders, and we reserve one for when we give quotations. There I must suppose that you are no better than my clients always were. There are quotations with a promise they definitely cannot keep, but there are also quotations with a delivery which they take seriously themselves. For these we have a special colour of paper and we put this into the load board—the load strips corresponding to these orders, at the promised date. We make a special point to take them out if we have not got an answer within a given time limit, and at the end of that limit get the sales department to get the answer. So we admit a limited schedule in tenders.

MR. A. SYKES : Mr. Hijmans seems to know what goes on in this business. I would like to ask one more question. He referred to the number of small books which were collected from various members of a progress staff, and explained that by his system he would put this information into a more regular form and thereby eliminate these books. Does he find that that happens in practice, or does he find that the books are still there after his system is installed ?

MR. HIJMANS : In most cases we have been able to work in the spirit of organisation sufficiently to have the workpeople really co-operate—co-operation in not only following our instructions, but constructive criticism of them. The main point is to get the " microbe " into the whole concern in such a way that they come and ask for the information. I would not tell you that I have always put away all books. There are certain men who keep to their little book, and we let them, but we make an earnest effort to get so deeply into the pyschological reasons why they want a book that we usually discover a little snag in our own project that makes them want to write it. So we do not fight these books, but we question so deeply into them and we try so earnestly to see why they are kept, that we come to discover our own faults. I think I am not boasting when I tell you that in most cases we finally get them out.

MR. F. R. SMITH : I should like to ask Mr. Hijmans whether he finds from experience that his system reduces what I call " overdues to the customer," or late deliveries. If so, I wonder to what extent ?

Does he find that customers who have been given a delivery promise which seems to be a very lengthy one, tend to make less requests for shorter delivery when they know the basis upon which the planning date has been obtained? Does the knowledge that this progress system is in operation give confidence to the customer by making him realise that he is getting a "fair crack of the whip"? One learns mostly from difficulties, and I wonder if Mr. Hijmans can tell us what has been the most frequent difficulty that he has encountered in applying the system.

MR. HIJMANS: In every case "overdues" have been substantially reduced. That is all the answer I am ready to give to the first question. Giving percentages is entirely futile, because they are determined first of all by the amount of total overload the company is prepared to carry. In such times as these the promises will go to the utmost stretch, and we all promise what we know we hope to give, and are not going to. In times of depression on the Continent there was always delay, because the number of workmen was so reduced that to occupy them you had to lengthen times. So the question of overdues is in the hands of the management and not in the hands of progress departments, and depends on the economic conditions of the moment. The result and the value of a progress scheme cannot be measured by any percentage of overdues, because you can force it to one side or the other if you are the management. That there is a substantial reduction compared to the overdues that would happen otherwise, I can assure you, and I think that there has not been any exception to that rule.

To the question of clients being more ductile before a well organised graphical planning, I can answer from some cases definitely in the affirmative. It depends, of course, on the management. There are firms which carefully ask us to put something before these boards so that nobody outside the firm can see them. If you have a firm which has one delivery for the clients and one for themselves, the progress department would not be of any use in this respect, but we definitely know from different examples that keeping deliveries lengthens the delivery the client is prepared to let you have, if you can give him a real argument. There is a question of mutual confidence. I remember one particular instance of a machine shop in Holland which was to have a very important order from the State Mines, who tried to force delivery, and then they were invited to come to the factory and they were put before a board such as I have shown you and they said, "You see that gap—that is where your work ought to go in. We are prepared to put it in, but we can only give you that delivery." They got the order. It is certainly a fact that a man who goes to see an important client must make his mind up before. He has to do the same as the man who has a good cost price system. He knows he cannot go under such price.

You know that good costing is the basis of price. Even if you lose an order here and there, there are cases that by knowing your cost you have been able to convince and even get an order above the price of the competitor. It is exactly the same with deliveries. To that extent, certainly, there is an influence on your customer.

MR. GROVER: If there are no other questions, may I just make one or two remarks by way of concluding this very happy evening. There is one thought which I wish to emphasise, and that is the idea which was thrown out by the lecturer in the very early part of his lecture, where he said that his work was devoted to "renewing the vigour of our daily life." Now there he was touching upon something which is fundamental in our labour conditions to-day, and that is the question of manufacturing by people who are confined to doing the same sort of work for an indefinite period. There is another point which is worth mentioning, and that is the absence of antagonism between himself and the firms and workpeople of the factories which he has gone into. I think it is one of the outstanding features of his lecture to-night, that he has shown that in every effort to increase the productivity of a factory he has never on any occasion sought to blame labour for its slackness, and he has, on the contrary, sought to engage the services of labour, and, as he himself said, get intellectual assent to every proposition which he put forward. He spoke of haste. I was speaking to another gathering the other night, and I made the remarks that insofar as we could substitute *rhythm* in our processes for *haste*, so we shall increase the efficiency of our manufactures.

## Discussion, Edinburgh Section.

MR. A. PEET (*Section President, who presided*): After hearing Mr. Hijmans' lecture on charts, the old saying of "Where would the Navy be without charts?" should be "Where would the production engineer be without charts?" It is a most interesting system, and the simplicity of how it can be done is the main thing that interests us all. As he says, you have the foremen running round here and there, having bits of paper, and being passed a little pile of books. If it is on a chart, it is plainly there and easy to get the information required.

MR. BURNS: One thing that struck me was that Mr Hijmans did not gloss over the difficulties that arise in any factory. The application of the Gantt chart to the rubber industry looks rather a proposition to me. Take a department in the rubber industry, say the moulding department, which produces a mass of different articles and may have anything up to 400 jobs in hand, all "urgent," "wanted at once," "as soon as possible," or "per return of post"—I daresay Mr. Hijmans knows the difficulties regarding that. I don't know whether it would be necessary to inform the customer at the time of placing the order that he must give a definite date, or whether the progress man gets his date from the chart as to when it can be delivered, but with regard to a moulding department it would be rather difficult.

MR. HIJMANS: I have not exactly worked in such a department, but one of my partners is actually handling a department like that. I can mention another industry in which I have personal experience in which the same difficulties exist, and that is the glass industry, crystal and fancy glass. The assessing of time is necessary, and it is one of the things that make people shy off from starting progressing, that necessity of assessing man hours or machine hours. An interesting feature of charts is their connection with budget control in the very best sense of the word. If you make a capacity or load chart, you are making advance estimates of labour efficiency and posting these estimates as your blue lines creep slowly from left to right on the chart. In factories where rates are difficult to set, or there is not time to set them, we definitely use "Gantt" charts to approach the question of estimating by budgeting labour in this way. This is very interesting in dealing with departments where labour often has a strong bias against piecework. We assess in pencil with a view to progressing only, and tell the foreman that we won't reproach him if he is an hour wrong, because in the long run

that will balance. Encouraging people to make these rough estimates and form a graphical picture of what they would like to do, and having that picture followed from hour to hour by real data, is perhaps the best way to efficiency in such departments. Even if you start very badly, you are bound to know much more about assessing within a month, as practice has shown us in similar industries. On the other hand, the question of calling in time for material is extremely important, and the multiple date line in such cases will often give great advantages. The choice between machine hours and man hours depends on the conditions of the case in hand. We often use both units, with cross reference from one to the other.

MR. BENHAM: From my own experience on shoe planning I would like to venture a criticism, if I may, on these stopgaps you spoke about. If one is working on a ten days' cycle and you have got 10 stages, for example, to fill in with work, but assuming your first stage is progressing faster than you anticipated, you have got a stopgap there. The whole 10 operations surely must coincide to bring the final job out at the time anticipated. It is just this particular provision you make for reserves and stopgaps which, in my own experience, I cannot fully appreciate. How, for example, can you use your stopgap by filling in a fifth stage operation, which cannot obviously start until stages 1-4 are complete to fill in there? In our own particular case, experience has proved that it is in our own interests to fill our chart up 100%. We have found it advisable to make a 100% plan, rather than allow the 10% or 15% you have advocated at certain stages of the operations.

MR. HIJMANS: I do not think that the type of graph I have shown here would be the most appropriate for that sort of industry, because you have an example there, not of continuous work, but of intermittent-continuous work. You have very short duration operations, and very numerous, as far as I know, and to this sort of industry we do not apply these charts, mainly for the reason you give. It would take me too long now to show the very different kind of charts we use in intermittent multi-operation industries.

MR. BENHAM: I take it that you are more or less in agreement with the 100% planning for shoe production, with no allowance for middle stage stopgaps?

MR. HIJMANS: Of course, shoe manufacturers can be extremely different. A glass factory can be nearer to a foundry than one foundry to another.

I have in mind those industries I spoke of—intermittent—continuous manufacture, where your main object is to make a product without break in the line of operations, because the importance of labour expended is limited compared to that of the extent of floor space, material in hand, and other different factory and delivery questions, and therefore the full occupation of machines

can be sacrificed to the speed of work flow. I suppose that is the case with you, and there we constitute a line of manufacture as if we were always making the same shoe, apply that during a certain time and then change over. There is another industry which is similar, which we handle on that basis, and that is the tinplate box industry, where we have all sorts of cans and tins. In these rapid running industries our principle is to sacrifice the 100% of machine occupation to get the 100% manufacturing speed. Another example is the wooden box-making industry, where you have rip sawing and cutting off. Cutting off is always shorter than rip sawing. In one factory they piled up wood after cutting off, waiting for rip sawing. It proved to be less costly to let the cutting off man have idle time than putting into piles and taking out.

A vote of thanks to Mr. Hijmans concluded the proceedings.

# DIE-CASTING.

*Paper presented to the Institution, Preston Section, by Dr. Arthur Street.*

IT is quite likely that many of you here are very well acquainted with the die-casting process, but I should imagine there are also some, who, so far, have had no occasion to use die-castings. For the benefit of those who are not so familiar with the process, I am proposing to give a brief introduction before passing on to more detailed considerations.

Die-casting is a metallurgical process which caters for the production of bulk quantities of small and medium sized fittings. Die-castings are made whose weight ranges between 1/50 oz. and 50 lb., but I should say that the average weight of die-cast articles lies between a couple of ounces and 1 lb. The quantities which are involved are rarely less than 500, and, unfortunately for die-casters, the numbers rarely exceed 500,000.

The process is generally applied to the fabrication of non-ferrous alloys of low or medium melting point. As a rough guide you can reckon that about two-fifths of die-casting tonnage is made up of aluminium base alloys, another two-fifths of the zinc-base alloys, and the remaining one-fifth is made up of brass, aluminium bronze, magnesium, lead, and tin base alloys. Die-casting in the high melting point alloys is still very much in the experimental stage. It is quite possible that sooner or later we shall be able to make successful die-castings in monel metal and cast iron, but at the moment, although a lot of experimental work is still being done, I would not like to suggest that die-casting in the high melting point alloys has become economically possible.

The world "die-casting" describes itself: it indicates that a metal mould is made, and that the alloy is cast into this permanent die. There are two well defined groups of die-casting production. The simplest and the oldest method is called "gravity die-casting." This process is not very much different from the operation of the ordinary foundry. The mould is of course a permanent one, but the metal is poured from a ladle into the die, the cores are hand operated and the die is opened and closed by the workman. Because the impression of the article is cut in the steel die we are able to

get a good and accurate reproduction. You can reckon that a gravity die-casting will have a general acuracy of plus or minus five thou. Medium sized holes can be cored providing a certain amount of taper is given, and quite complicated jobs can be produced.

The gravity die-casting process has several advantages but it also has one or two disadvantages. The cost of a gravity tool is low—an average figure is about £10—and because of this, and because the setting-up of a gravity die is comparatively easy, we can use gravity die-casting for production of only small quantities, such as 500 per annum, although of course gravity die-casting is used for big quantities as well. All the time you are considering the gravity process you have to remember that the human element comes in very strongly. The operator may close the die altogether in such a way that the closing pressure on the two sides is different and he may not always check up that the steel cores have been located securely. Then there is another thing; the operation of a heavy die calls for a considerable amount of physical strength, so that at 5-0 p.m. on a hot July day, efforts may be expected to flag.

The other process, pressure die-casting, manages to obviate most of these disadvantages. It is interesting to note, by the way, that this is really a distinct process. Although the same organisation is frequently engaged in production by both methods, the technique demanded is different. For instance, as will be mentioned later, an alloy ideal for pressure will not be so suitable for gravity die-casting and vice-versa. However, to return to the pressure process : the two halves of the die are mounted on slides, usually one half is fixed and the other movable. The cores are mounted in the die and they are inserted and extracted by mechanical means and when the casting is finished it is lifted from the die-face by a series of ejector pins. The most outstanding characteristic of the pressure process is the injection of the alloy. This is forced into the mould under a high pressure, which may be anything between 600 lb. and 6 tons per square inch, depending upon the type of machine which is employed. The velocity of injection is so high that you really cannot truthfully call it a " casting " process. One has to try to visualise the metal being hurled into the die at a velocity which I suggest is of the order of 30 miles an hour.

The pressure die-casting process allows the attainment of high-speed production ; as a general average you can reckon that pressure die-castings are produced at the rate of 1,000 shots per day, compared with about 150 or 200 per day gravity die-castings. This figure of 1,000 shots per day only represents an average for ordinary jobs, because there are certain simple designs which lend themselves to very fast production. By arranging the die movement, core movement, ejector movement, and the injection of the metal, to be

actuated by a series of cams, the whole process can be made continuous and automatic, and under such conditions outputs approaching 1,000 shots *per hour* have been obtained. The only limitation is the time taken for the metal to cool, and, by arranging suitable water-cooling channels in the die high speeds can be made possible.

**Choice of Alloy.**

I don't think anybody has really decided what it is which makes one alloy suitable for die-casting and another alloy not so useful for this purpose. I would not like to be the one to pass a final opinion, but we might try to consider some of the qualifications which an alloy must possess before it becomes "die-castable."

(1) The alloy must have a reasonably low melting point. I shall come to the question of die life later on, but I think it will be obvious that the nearer the melting point of an alloy approaches the softening temperature of the die steels, the more severe will be the wear on the tools. To give you an example, zinc-base alloys, with a melting point of about 400°C. may have a die-life of 500,000 shots or more, while with a brass die-casting, melting point about 900°C., we reckon ourselves lucky if a tool lasts more than 20,000 shots.

(2) The alloy must not attack the die steel. You may have noticed that I have not spoken about "metals" being die-cast, I have always said "alloys." Zinc, for instance, can be die-cast quite nicely, provided it is very pure. But there is just one disadvantage, pure zinc is one of the metals which has a solvent action on the steel and so, before we have gone very far, our die would be completely galvanized. However, this action can be countered. If aluminium is added, even a fraction of 1% this solvent action is eliminated. In practice, 4% of aluminium is added and the alloy obtained, which does not galvanise the die, has also high mechanical strength.

(3) The alloy must be strong at high temperatures. When the die-casting is made it cools very rapidly indeed, much more rapidly than a sand-casting cools. The first 200 degrees of cooling take place in the space of a few seconds, and during this time the metal is rapidly contracting. Particularly in complicated jobs the contraction takes place against the constraint of the features of the steel die, so that it is vital that alloy be not hot-short, or it will crack when it is die-cast. This is almost certainly the reason why it is possible to pressure die-cast 60/40 brass, but why we cannot die-cast ordinary commercial 70/30 brass.

You can divide die-casting alloys into five groups. First there are the low melting point tin-base and lead-base alloys. These are

rarely used nowadays, and I do not think it would be worth while spending time on them.

## Zinc Base Alloys.

The next is a very important group, the zinc-base alloys. I have already mentioned that these are based on the composition—zinc 96%, aluminium 4%. This may be called the " basis " alloy and there are three variations, all of which are widely used. (1) This is simply the " basis " alloy with 4% aluminium. (2) This contains 4% aluminium but has the addition of 1% copper. (3) The 4% aluminium again, but in this case 2.7 to 3% of copper is added. With increasing copper content the tensile strength and hardness increase, but against this we have to set the fact that the alloy with 2.7% copper is not so ductile as the others—and even more important—it is not so permanently resistant to impact. It is quite likely that during coming years the alloy which is most favoured will be that containing 1% copper. This has a tensile strength of 17 to 18 tons per square inch, a hardness of 75 Brinell, and an impact value of about 19 ft./lbs. The great and outstanding virtue of these zinc-base alloys is that they are admirably suited to the pressure die-casting process. I have in front of me a number of zinc-base alloy pressure die-castings, ranging from very tiny ones to a pressure casting which weighs 14 lb.

You probably know that not so many years ago the zinc-base alloys were not favoured by engineers, but owing to the striking advances which have taken place in both the materials themselves and the methods of production, these alloys are now a group which no user of bulk quantities of fittings can afford to ignore. Not only are they used for decorative parts, but they are used where quite heavy loads have to be taken. For example, zinc die-castings are employed as gears, switchgear control components, parts of hoist mechanisms, and in America there is a small lathe which embodies 43 separate zinc-base die-castings.

## Aluminium Alloys.

Successful die-castings have been made in a wide range of aluminium alloys. However, there are two which have proved to be specially suitable for the processes involved. One is the alloy containing 11% copper, known as " L 8 " and the other the alloy containing about 12% silicon—the L 33 composition. Speaking broadly, you can reckon that the copper-containing alloy is rather more suitable for gravity die-casting, and the alloy with silicon lends itself to pressure die-casting work. The melting point of these aluminium alloys is about 150 degrees higher than that of the zinc

base alloys, and it is mainly because of this that we have to consider the question of die-life rather carefully. Thus, for instance, while a complicated carburetter can be die-cast in zinc-base alloy, it would not be possible in aluminium. It would not be wise to attempt to cast the small holes and complicated details, using the higher melting point alloy.

Although die-casting is essentially a process which aims at producing the finished article, there is no point in producing the job, finished in all its details, if it means that serious damage will be done to the expensive dies which are used. In these days drilling is such a cheap and rapid operation that, particularly in the die-casting of aluminium-base and copper-base alloys, it is best to consider the production of small holes and threads by a subsequent machining operation.

## Copper-base Alloys.

We now come to the fifth large group of alloys, and of these the two in commonest use are brass and aluminium-bronze. Brass only occupies a secondary position in the die-casting industry, although the 60/40 composition can be die-cast by both the gravity and pressure processes. Generally the cost of such die-castings will work out at rather a higher level (especially for simple and straightforward parts) than the well-known brass hot pressings or stampings. However, if the job is complicated, with core movements in several directions, the use of brass die-castings will be well worth considering.

When you come to consider the alloys available for die-casting it is clear that there are many cases where the zinc-base alloy can be used with advantage in place of brass. There are two outstanding qualities which brass possesses, however, that bring about its use in certain cases. The first is its colour. There is still in this country quite a prejudice against " white metals " and a number of users find it difficult to understand that a white metal like the zinc alloy is capable of being as strong as a yellow metal like brass. The second reason is that brass, almost alone of the die-casting alloys, is capable of being soldered. The other die-casting alloys contain aluminium and this makes soldering a difficult operation. By the way, many brass castings are chromium plated, presumably to conceal the colour, so isn't it more logical to start with a white metal ?

While I am talking about soldering I would like to point out that the difficulty of soldering the other alloys has probably done a tremendous amount for the benefit of die-casting. Quite often users have decided to go ahead with the use of a die-casting in,

shall we say, zinc-base alloy, and then found during their investigations that the use of a die-casting would not allow them to do a soldering operation which they had considered essential. When this is realised, two thoughts come to the mind ; they can give up the use of the die-casting or they can put on their thinking caps and consider how they can dodge the soldering operation. Now soldering is a rather messy process usually performed to join one part to another and very often, when users have got to this stage, they think to themselves : "Could we, by using die-castings eliminate the wretched soldering operation and make the job as a one-piece article ? " And very often they find to their considerable delight that they can do this.

I am afraid I have strayed from the subject and must not forget there is still one important alloy to discuss. This is the yellow metal "aluminium-bronze." Aluminium bronze is based on the composition—copper 90%, aluminium 10%—although we generally add between 1 and 2% of iron to refine the grain size and increase the strength. Aluminium-bronze is an alloy which particularly lends itself to gravity die-casting production. You probably know that although this alloy can be foundry cast, it presents a number of serious problems if brittleness and porosity are to be overcome. However, when we die-cast aluminium-bronze these difficulties are considerably lessened.

It is interesting to note that in its die-cast condition aluminium-bronze has a tensile strength of about 35 tons per sq. in., while in the foundry cast state strength is less than 25 tons. This considerable increase in strength in the die-cast state is partly due to the grain refinement which occurs when the metal is chilled in contact with the steel mould and partly due to metallurgical changes when the alloy is chill-cast.

Aluminium-bronze is essentially a gravity die-casting alloy, and in the gravity cast condition we are able to get excellent results. Holes can be cast, provided they are not less than $^3/_{16}$ in. diameter, and the die-castings generally have an accuracy of plus or minus .005 in. per inch.

**Die-life.**

A friend of mine was talking to a German die-caster not very long ago, and knowing something of the wonderful results which are being obtained in that country, he asked what limits the German die-casters worked to. The German looked rather puzzled and replied that they did not work to any limits, they made the job accurately. I am not quite sure whether this was a bit of political propaganda, in die-cast form, but I am confident that, in England at any rate, there are a number of factors which

have to be watched very carefully to make certain that it is the " accurate " job which is being produced.

Before a die-casting can be dead accurate there are three things which have to be controlled. First of all the die must not wear in the slightest degree ; secondly, the die must be opened and closed and cores must be inserted and extracted in such a manner that the dimensions of the die-cast product remain exactly the same ; thirdly, the casting must contract so that it lands up at the correct dimensions without fail. Let us consider these three points in their reverse order.

The question of contraction is an important one, because the shape that is sunk in the die is always slightly bigger than the dimensions of the job which we desire to obtain, and it is often difficult to determine just how much shrinkage to allow for. I have here a long, thin die-cast strip which played quite a lot of tricks in contracting. There are a number of rivets and cast-in studs included in the die-casting and during contraction these had the effect of holding on to the die and preventing the casting from shrinking to its fullest extent. Consequently, although the theoretical amount of contraction is about $^1/_8$ in. to the foot, this particular die-casting only condescended to contract about $^1/_{16}$ in. to the foot.

To a greater or a smaller extent this factor must be considered in all die-casting production. The more uniform a job and the more regular its production cycle the more accurate it is likely to be. Now, in spite of all the snags I have talked about, I would like to stress that the contraction can usually be controlled very closely indeed and in most pressure die-castings we reckon that an accuracy of plus or minus one thou. per inch is quite feasible.

The second factor which I mentioned was the correct positioning of the members of the die during casting. Both gravity and pressure die-casting are affected by this trouble. In gravity die-casting, as I admitted earlier, the human element is bound to crop up and occasionally we have to expect that the die-operator will not close the die together properly, so that the casting will have to be rejected for being oversize. Similarly he may not have positioned his cores correctly, again leading to a scrapped casting.

In pressure die-casting quite a different kind of trouble is experienced. Every time the metal is injected you get a heavy bursting pressure set up, and one of the chief problems of the process is to prevent the die from springing every time a casting is made. Although most die-casting machines are designed to hold a die together securely, yet it is always more difficult to attain accuracy across the parting line than in a part of the die-casting which is

produced from a single die block. From this it follows that a design which involves a number of die block movements will not be so accurate as one produced in a straight-forward " two-part " die.

Now we come to the first of the die-life considerations—the wear on the die itself. In pressure die-casting there is a tendency these days to make every tool of a heat-treated alloy steel, but whatever steel is used a number of effects become apparent sooner or later. The continual impingement of the alloy may cause hair cracks to appear on the face of the mould and these are reproduced on the surface of the casting. Hair-cracking is particularly met with in brass pressure die-casting tools, owing, of course, to the high casting temperatures which are involved. Usually these cracks appear after about 5,000 shots have been made. If surface appearance is not very important the hair cracking does not mean that a new tool must be made, and in such a case the die can go on being used until about 20,000 brass die-castings have been made.

Cores, particularly slender ones, will show signs of wear more rapidly than main parts of the mould. This wear of cores is not only due to the thermal effect but it is due to the mechanical effect of continually pulling the cores out of the contracting die-castings. Provision must be made for the wear of cores, and the design of the die should be so arranged that cores can easily be replaced. If any of you happen to be users of die-castings I suggest that you should give periodical checks of the diameter of cored holes.

In general we try to make pressure die-casting dies in as few pieces as possible. You can quite understand that if a tool were built up of a number of small die blocks which were fitted together, the unequal contraction and expansion of these jig-saw pieces would result in the rapid deterioration of the tool.

You will, of course, appreciate that the melting point of the alloy has an outstanding effect on the die life ; for instance, a life of 250,000 or 500,000 is quite usual in zinc-base pressure die-castings, while in the pressure casting of brass we think ourselves lucky if we get 20,000 shots from the one tool.

### Influence of Quantity and Design on Cost.

Essentially, die-casting is a process which produces large quantities of accurately cast components at a low cost. Die-castings, however, are never sold at so much per lb. like the majority of foundry castings, but the cost of each die-casting is calculated. There are a large number of factors which have to be taken into consideration. For instance, there is cost of raw material, the making of the die, the hardening of the tool, the testing and all experimental work which has to be done before the die is running

properly. Then we have to take into consideration the production speed. For instance, some pressure die-castings can be produced at the rate of 2,000 a day or more, while other larger and more complicated jobs only result in 150 or less. Then sometimes we have to remember that a simple die-casting can be produced on a machine operated by one man only, while occasionally there are very complicated jobs whose production needs the services of four or more men. This occurs, for instance, when a loose core has to be dismantled after the die-casting has been produced.

Quite apart from the obvious things like material cost, there are two big factors which crop up which I do not think are always fully appreciated. The first is quantity and the second is design, and I should like to discuss these in rather more detail.

The question of quantity, I would emphasise, does not solely consist of calculating what proportion of the die cost will be involved in the price of these castings. The actual cost of manufacture of the die-casting varies with the quantities which are to be produced. For instance, if only 200 pressure die-castings were to be made, the making of this small quantity as a pressure die-casting would probably take about three days. This is because on leaving the tool room the die has to be " run-in," the cores and the ejectors have to be eased, the die has to be got up to the correct working temperature, so that the initial production is very slow indeed. Furthermore, the making of the first 100 or so die-castings has to be supervised by the foreman of the foundry and the toolmaker who made the die will usually have to carry out slight adjustments to the runner and the venting of the die, so that the production of these 200 castings would be a very expensive matter indeed. After the first few hundred castings have been produced the die seems to get into its stride and the production speed gradually rises.

With gravity die-castings the same problems occur, but they are only involved to a much smaller extent. As a general rule you can reckon that gravity die-casting is economical for between 500 and 5,000 castings ; pressure die-casting starts to show its real value when quantities greater than 5,000 are concerned.

I think we can now come on to the question of design. This affects the cost of the die-casting and also the accuracy and the general effectiveness of the job. Now when you are considering design you have to bear in mind that the die must be constructed in two halves, which close together for the casting operation and which are opened for the removal of the finished job. I think you will see that the quicker the die can be opened and closed, the the cheaper the die-casting will be ; consequently, if you have a part which can be produced by the simple opening and closing of

the die, that part should be cheap, but if you have a job which involves difficult core and die block movements, the production cycle will be slowed down.

Perhaps first of all we might consider the question of core movements. A cored hole can be produced in one of three ways. If its direction is at right angles to the parting of the die, the core can on occasion be made by part of the die-block. There is a great advantage in having holes cored by the die-block itself, for the accuracy is appreciably greater than it would be if the hole were cored by a separate movement. At the same time we have to remember the possibility of wear must be taken into account and thus it would not be sensible to core a long slender hole, $^1/_{16}$ in. diameter, by part of the moving die-block, because the piece which cored the hole would have to be renewed at intervals and it would be silly to have to renew the hole die-block simply because the slender core pins started to show signs of wearing.

For all slender holes and for all holes which are inclined at an angle to the die movement, separate cores are used and these work in the die so that they can be pushed forward into position when the die-casting has been made. As a general rule each direction of core movement means an added complication in the die and consequently each direction of core movement will mean a certain increase in the cost of the die-casting. In very many cases it pays to try to rearrange the design in such a way that the core movements are minimised.

There is a third way by which cored holes are made. This is when the hole is designed so that the steel core producing it could not possibly be withdrawn in a straight line. When this happens we are confronted with the problem of undercuts, and I should like to discuss this question in some detail.

If we consider a shape like a bottle you will see that it would be very awkward to produce this as a die-casting, because the core producing the inside would be of much greater diameter at its remote end than at the end which forms the neck portion. This would mean that when you made the die-casting, the metal would solidify around the core and you would be unable to pull the core through the neck of the bottle. This kind of design would be almost impossible to produce by die-casting. It would mean that a core would have to be made up of a large number of separate pieces and when the bottle shape was solidified you would have to pull out one central piece and then shake the remaining core pieces, and pull out another one, and go on pulling out slices of the core through the neck of the bottle till you had extracted the whole lot.

But if you wanted to make a bottle shape by die-casting there would be one sensible way of doing the job. You could make the

part in two pieces. The one part would be the case of the bottle and the other part would be the remainder. By casting the bottle with the bottom open, you would be able to pull the central core through the wide opening at the bottom, and of course the plate portion would present no difficulty. As regards joining the two die-castings together, you could probably arrange to cast threads on both the diecastings so that the two pieces could be screwed together.

Although we are not usually presented with bottles to die-cast, the question of undercuts does arise to a considerable extent, and usually the core producing the undercut is designed in such a way that it may be dismantled piece by piece. Before I leave the subject of cored holes and recesses, I would like to remind you that every core and every movement at right angles to the die-parting means that a taper or a draught must be allowed. This taper varies with the alloy employed and with the design of the part. For a zinc-base pressure die-casting the taper is small, only of the order of between one and two thou. perinch, but for aluminium alloys and aluminium-bronze the taper has to be between 10 and 20 thou. In designing a die-casting it is important to consider the section with particular care. You have to remember firstly, that very thin sections can be die-cast, for instance, in zinc-base alloy pressure die-casting you can get down to $^{3}/_{64}$ in. or even less. It is desirable to select the minimum section for a number of reasons. First of all, the cost will be reduced by so doing ; secondly, the production speed will be increased because the thinner casting will solidify quicker, and thirdly, you have to remember that the strength of an alloy in its die-cast condition is greater than it is in the foundry cast state.

If a designer is out for strength in a die-casting, it is best to have a reasonably thin ruling section, but to include a number of ribs where the stress is specially severe. It is a funny thing that there is still a big tendency in designing die-castings to imagine that sheer bulk and thickness provides suitable strength. If you were designing a bridge you would not dream of constructing it with heavy billets of steel, 12 in. by 6 in. in section, but you would use girders which were carefully designed and arranged, so that the bridge should have the maximum strength with minimum weight. The use of die-castings does allow you to do this sort of thing.

Another thought which I would like to get over connected with ruling section is that the section should be made as uniform as possible. If, for instance, you had a heavy block of metal which had to be joined by a thin web, you would be sure to run into trouble because the thin section and the thick would contract at different rates, and the one would pull on the other and there would be the possibility of a contraction cavity in the thicker section. In die

casting it is possible to relieve thick sections, and it should be the aim of users to see that section is as uniform as possible.

I think you will realise that the question of designing for die casting could be talked about almost endlessly, but before I finish there is one thought which I would like to stress. A user is in the position of having to design a die-cast component, and it is a very good plan to consult a die-caster while the design is in the preliminary stages. You will find that die-casters are quite nice people, and most of them are so interested in their work that it is more than a pleasure to be able to point out how a would-be user can simplify matters to get a better and more reliable job at the lowest possible cost. If you make sure that discussions about design are proceeded with at the earliest possible moment, there will be more chance of making modifications, if these are found to be advisable.

## Discussion.

MR. RYDER: I want to know in what direction experiments are being made to increase die life so as to make die-casting in cast iron and nickel silver alloy a practical proposition.

DR. STREET: We are almost entirely in the hands of the steel makers. At the moment there are no steels available that are good enough for making dies for high melting point alloys. When these die steels are ready for us, then we can go ahead with it. We have tried good quality tungsten steels for producing aluminium-bronze pressure die-castings and we got a die life of about 100 shots. We are quite sure that good enough die-casting steels will come along eventually.

MR. MILLS: What type of coating would you recommend for dies for high melting point pressure casting?

DR. STREET: There are a number of coatings suitable for dressing pressure dies; we have not yet found a perfect one. Many are of an oily nature, for instance, graphite, which can be either applied with a brush or dusted on. Every foundry has its own pet die-dressing and the representatives of the foundry suppliers are always pressing die-casters to use different die-dressings. However, any dressing used is in the nature of a lubricant for the moving portions of a pressure die, rather than a dressing for the mould surface. In gravity die-casting the dressing is primarily a coating for the mould.

MR. FENDER: With regard to pressure castings, I notice there are quite a number which are of very thin section. If pressure castings are made in thicker section do you get any trouble arising due to porosity?

DR. STREET: Frankly, yes; if you get a section of a die-casting greater than a $\frac{1}{4}$ in. you are quite likely to get a contraction cavity in the middle of the section, and for many reasons it is better to keep die-casting sections down to about $\frac{1}{8}$ in. By so doing you avoid porosity troubles—also, because the metal chills quicker, you get faster production. On occasions you must have a heavy section and in these cases you must be prepared for an occasional contraction cavity to come right in the middle. If, however, a die-casting design has got a heavy chunk of metal it is far better to try to core into that section, so that although it is a heavy lump of metal it is relieved sufficiently, so that you won't get a contraction cavity right in the middle.

MR. WOODS: Do you find it more difficult to die-cast in L.33 as regards getting sound castings? More so than in zinc alloy?

DR. STREET: Yes, definitely. It is more difficult. Not only because aluminium has got quite a nasty tendency to pick up gas, but also because the actual rate of chilling of the metal is quicker. When you start from a high melting point, about 550°C., it is more likely that air will get trapped in that metal than if you start from a low melting point. In pressure die-casting in aluminium alloy you are quite likely to get small contraction holes, about as big as a pins head, but by increasing the pressure of injection the tendency towards porosity is reduced considerably, and with very high injection pressures of the order of two or three tons per sq. in. we can practically remove porosity, although we are not able to guarantee that aluminium alloy die-castings shall be 100% solid.

MR. WOOD: Could you tell us what coating you use for dies for gravity casting and what method of melting the metal? We are conversant with the heavy types of die-casting and we have a certain amount of trouble with cast holes in heavy section dies unless we take special precautions. Is there any benefit to be obtained by controlled pouring in heavy section die-casting, i.e., speed of pouring and timing?

DR. STREET: I have so far only specialised in pressure die-casting production and we only do a small quantity of gravity die-casting work. The Leyland die-castings are well known to us and we very much admire the results obtained. I do not think anything I could say would be very helpful to you. With regard to the die-dressing, we use all kinds of things, mainly based on graphite lubricant, and we use oil-fired furnaces. As I say, our problems are not like yours.

MR. FENDER: Have you come across any efficient method of controlling die temperature in gravity die-casting?

DR. STREET: I have come across it in pressure die-casting. In gravity die-casting, however, if you start introducing such applications into the process you defeat the end of gravity die-casting, which is to produce a die-casting with as little trouble as possible.

MR. FENDER: Up to now, in our place, we can control melting temperatures, but we have found no really efficient way of controlling the heat of the die.

DR. STREET: There is so much of the human element in gravity die-casting that you cannot guarantee that you will produce a die-casting every two minutes. If you could, you could control the die temperature. All the while the die will be tending to cool down to room temperature, so that if there is any delay in production the temperature of the die would be falling and that would be one of the reasons why it would not be possible to apply methods such as you suggest.

MR. DODDS : During the lecture you stated that die-casting comes out to a limit of plus or minus .001 in. ; suppose I had a block with holes coming out plus or minus .001 in., would all those holes be constant on that block at the end of a day's work ?

DR. STREET : My suggestion of plus or minus .001 in. is that the average of a day's production would vary in these limits. For instance, if you had a hole an inch in diameter, and you measured the whole output of one day, the smallest diameter would be .001 in. undersize and the largest diameter would be .001 in. oversize. In pressure die-casting, even these slight variations are not so much due to the wearing of the cores, as to the varying rates of feed and production, and varying cooling of the castings.

MR. THOMPSON (*Chairman*) : I should like to ask if in your die-casting—say in cast iron, in changing from a deeper section to a lighter section—say from $1\frac{1}{2}$ in. to $\frac{1}{4}$ in., do you get any drawing effect by release of stresses ? In your experience have you encountered the specification S.A.E. 305 Silicon aluminium, with about 11 to 13% of silicon ? What is your experience of the life of the die on such castings if 5% tungsten chrome cobalt is used ? There are very severe limitations in your progession, entirely due to some limitations in my own ; there is no doubt about that; we are getting nearer every day, there is a lot of research work going on and I think there is a tungsten chrome cobalt made specially to withstand the high silicon content in the specification I spoke of.

DR. STREET : In connection with change of section, there is a tendency for heavy sections to pull on light sections, and in designing such a casting two things should be attempted ; first of all, the point where a heavy section merges into a light section should be amply radiused so that the sections blend correctly. If you don't do that there will be a contraction cavity just where the light section joins the heavy section. Another thing, a heavy section, if possible, should be relieved and it should be the aim of a designer of die-castings to make sure that these stresses do not occur. It should also be remembered that a heavy section will cool a lot more slowly than a light section—one is liquid while the other is solid—and so you get contraction stresses as well as drawing. Now as to the aluminium alloy to the American specification which you mention, this at the moment seems to be most favoured by the pressure die-casters, who use this 11 to 13% silicon alloy. We think it is better than copper-containing alloys, both from the point of view of physical properties, die life, and solidity.

MR. MILLS : On the practical side of pressure die making, seeing there is only a gate and no raiser, it is not necessary to use a good deal of air venting ?

DR. STREET : A casting like this big one here is run on the central boss. When the die is first made, it has very little venting indeed. The casting is run experimentally and usually just about half fills the mould ; from that we get the idea where the venting is to take place. Venting in a pressure die is usually round the parting line, not as in gravity casting where you make your die in various pieces and then vent by the gaps. You cannot make pressure dies as "built up areas" of small pieces of metal. You have to make them all as solid as possible. Wherever the die is vented, a flash will be seen on the finished die-casting, and this is clipped off by a subsequent operation. The pressure of injection is so high that the air is forced out. We do not employ raisers of any kind, but if we get any trouble in filling a rim we cut a channel round the casting and vent round the channel. This results in a die-casting with a thin flash all round—connected to a ring of metal which we hope contains any dross or porosity which has been expelled from the casting itself.

A VISITOR : How are the impressions in a die made ?

DR. STREET : We usually machine them ; it means that the die is distorted less if you machine an impression in, than by casting or hobbing it ; it you cast it in, the impression would not be accurate enough, and if you hob it in, the steel is locally distorted round the impression. Such a die would have a very short life. We always cut the impression in, except in very special cases.